Modeling and Simulation

April 2010

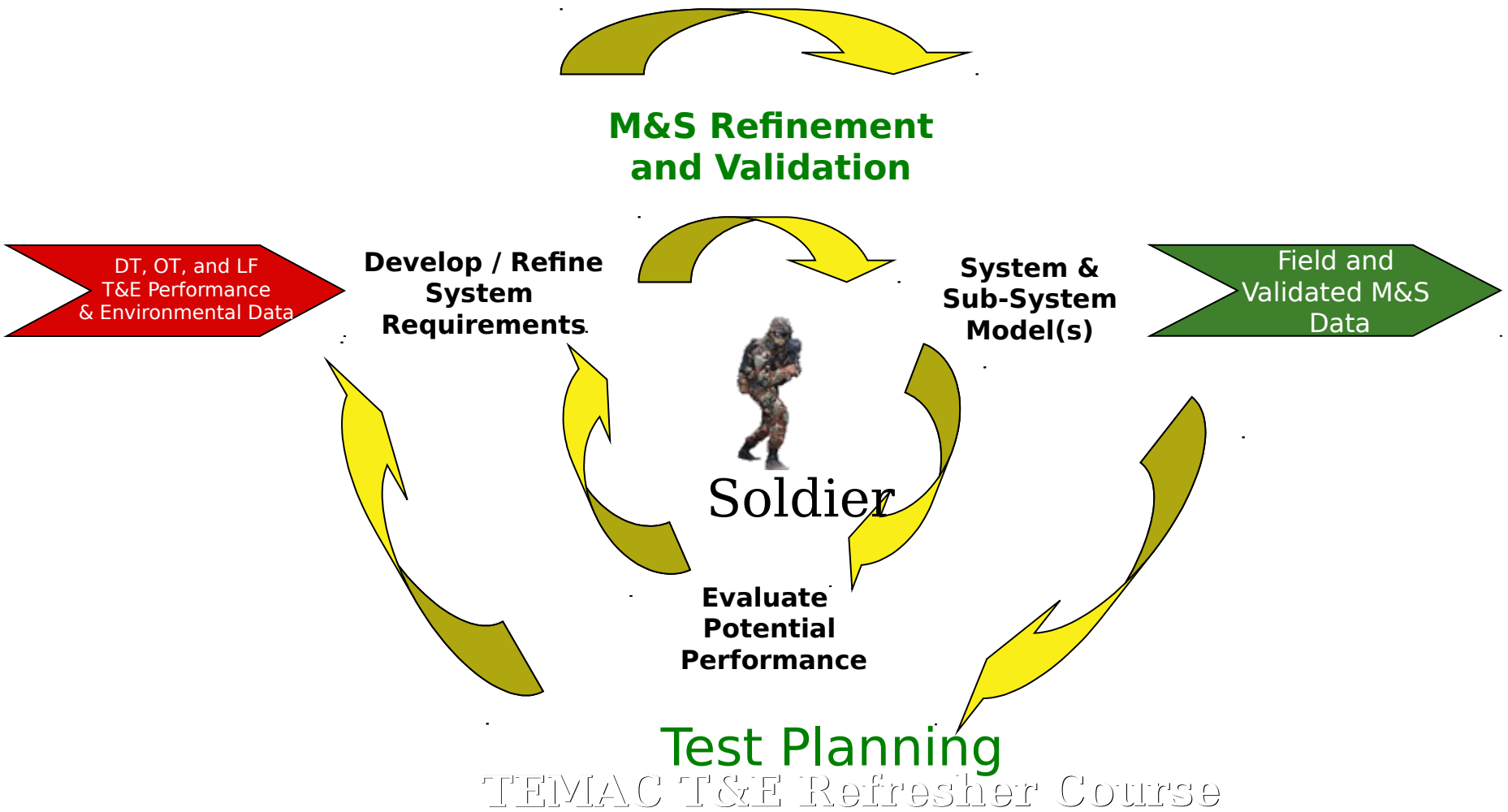
TEMAC T&E Refresher Course

Outline

- **Overview of DoD / Army M&S Guidelines**
- **Role of M&S in T&E**
- **Identification of M&S Needs**
- **Simulation Test and Evaluation Process**
- **Using M&S Results in System Evaluation**

- **M&S Accreditation for T&E**

M&S / T&E Synergy Cycle



Operation of the Defense Acquisition System

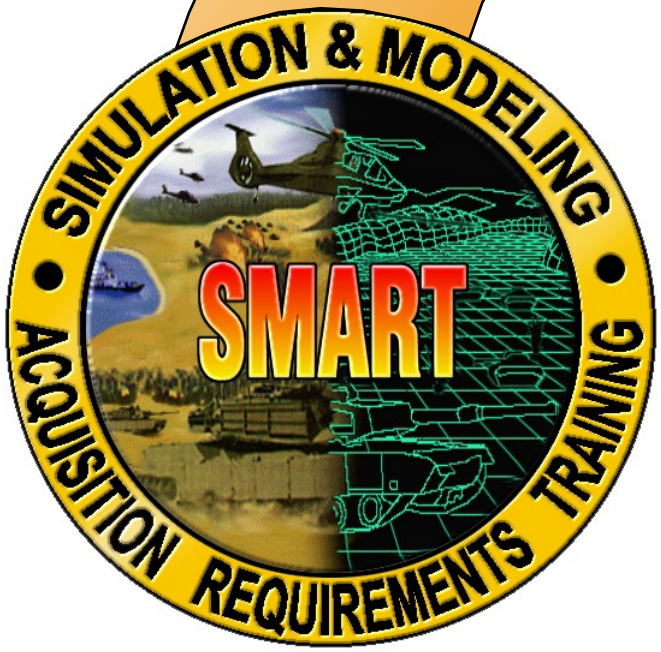
The PM, in concert with the user and test communities, shall coordinate developmental test and evaluation (DT&E), operational test and evaluation (OT&E), LFT&E, family-of-systems interoperability testing, information assurance testing, and modeling and simulation (M&S) activities, into an efficient continuum, closely integrated with requirements definition and systems design and development.

Overview of DoD / Army Guidelines

- **DOD Manual 5000.59-M, DoD M&S Glossary, Jan 98**
- **DODI 5000.61, DoD M&S VV&A, 13 May 03**
- **AR 5-11, Management of Army Models and Simulations, Feb 05**
- **DA Pamphlet 5-11, VV&A of Army Models & Simulations, 30 Sep 99**
- **SMART Planning Guidelines, DA, Sep 02**
- **ATEC Regulation 73-21, M&S VV&A Methodology, Aug 04**
- **ATEC Pamphlet 73-21 M&S VV&A Methodology, Apr 07**
- **Use of M&S in Support of T&E, DUSA(OR), 18 Apr 00**

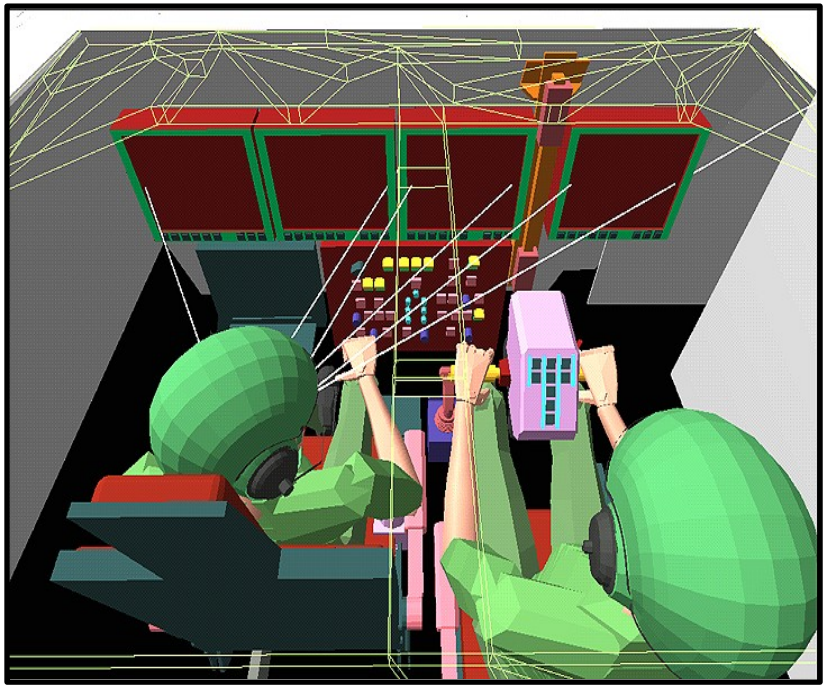
M&S - modeling and simulation
VV&A - verification, validation, and accreditation

Simulation and Modeling for Acquisition, Requirements and Training (SMART)



The Army's vision for SMART is a process in which we capitalize on Modeling and Simulation (M&S) technology to address the issue of system development and life-cycle costs through the combined efforts of the requirements, training and

“SMART” Test and Evaluation



Design Model for Assessing MANPRINT for Grizzly Breacher

- **Incorporate Long Term Planning for the Right mix of Simulation and Testing**
- **Evolve the Virtual T&E Infrastructure**
- **Conduct “What-if” Drills for Early Development of T&E Plans and Scenarios**
- **Accelerate the Synergies Between the Testing and Training Communities**
- **Ensure T&E Community Participation in all M&S Planning and Accreditation to Facilitate Acceptance**

Role of M&S in T&E

…we must continue to focus on, "…the real system, in the real environment, with the real operator…"

…I believe the notion of replacing testing with M&S simulation is inappropriate.

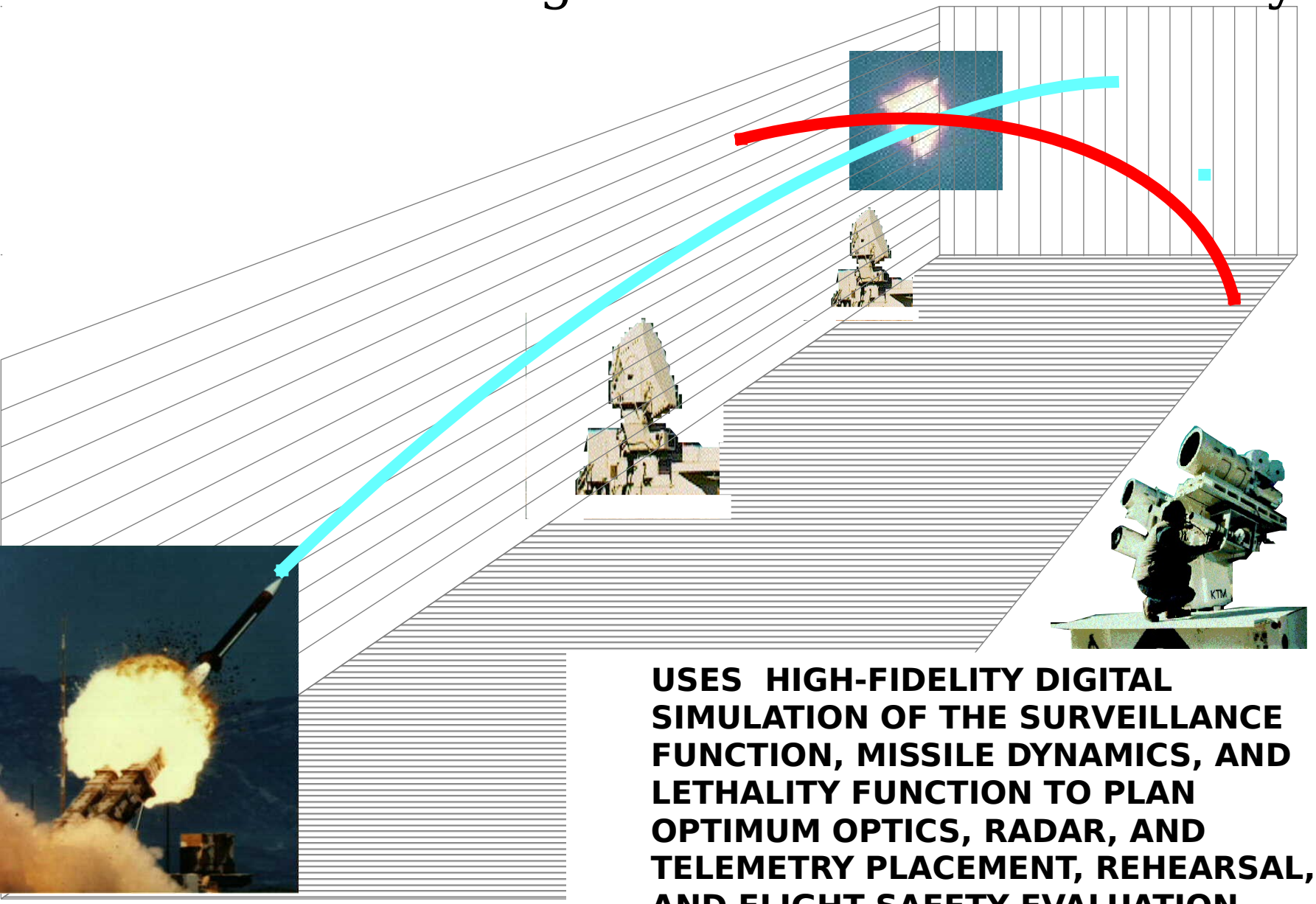
…however…

- **Models should help us predict performance throughout the mission space.**
- **Models should help us design tests to maximize our learning and optimally apply our resources.**
- **Models (stimulators) should help us replicate the environment during test to realistically stress the system under test.**
- **Model should add to our insight and understanding in interpreting collected data.**
- **Models using data and information gleaned from testing should be used to demonstrate the significance of conclusions reached.**

Thomas P. Christie
Director, Operational Test and Evaluation
Memo, 4 June 2002

I&S Integration with Testing (The Test Planning Proce

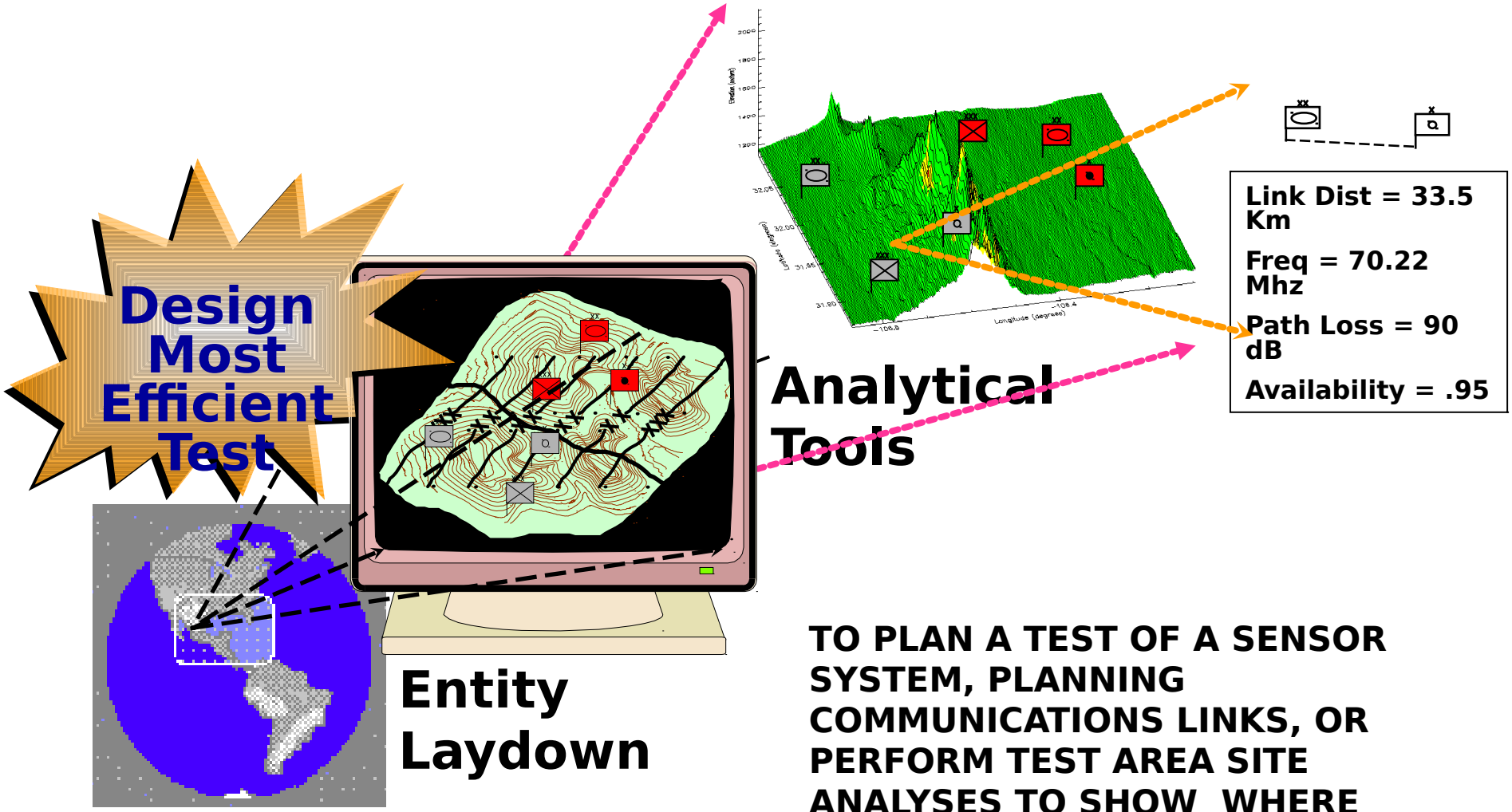
Mission Planning and Real-Time Test Analysis



USES HIGH-FIDELITY DIGITAL SIMULATION OF THE SURVEILLANCE FUNCTION, MISSILE DYNAMICS, AND LETHALITY FUNCTION TO PLAN OPTIMUM OPTICS, RADAR, AND TELEMETRY PLACEMENT, REHEARSAL, AND FLIGHT SAFETY EVALUATION.

M&S Integration with Testing (Test Scenario Design

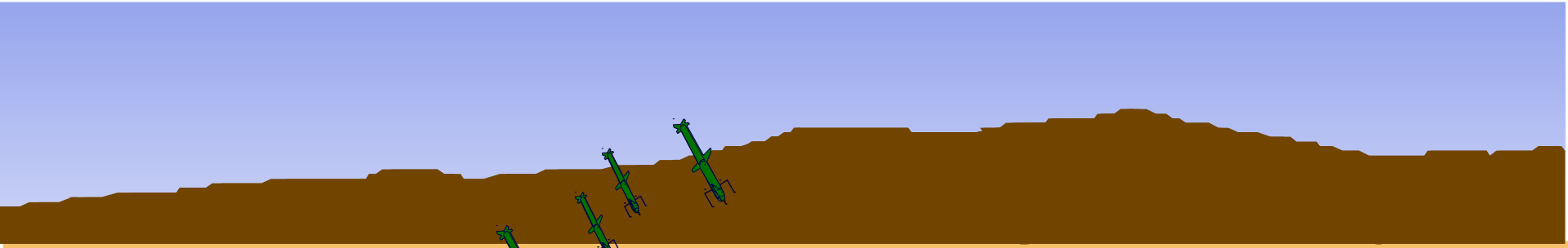
Virtual Electromagnetic C4I Analysis Tool (VECAT

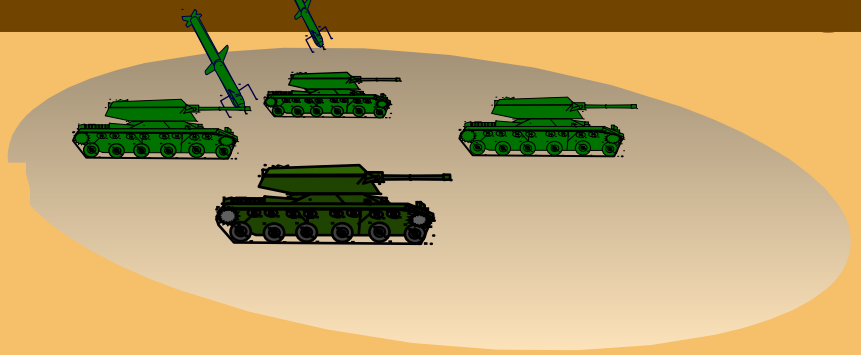


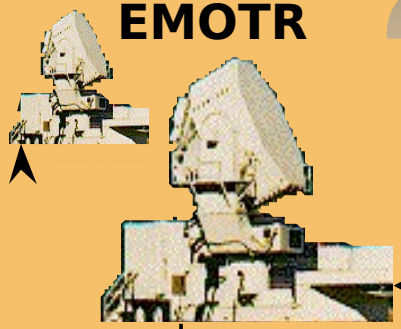
TO PLAN A TEST OF A SENSOR SYSTEM, PLANNING COMMUNICATIONS LINKS, OR PERFORM TEST AREA SITE ANALYSES TO SHOW WHERE SIGNAL BOTTLENECKS MIGHT OCCUR, AND IDENTIFY WHICH NODES TO INSTRUMENT.

&S Integration with Testing (Drive Test Instrumentati

Smart Munitions Test Suite (SMTS)

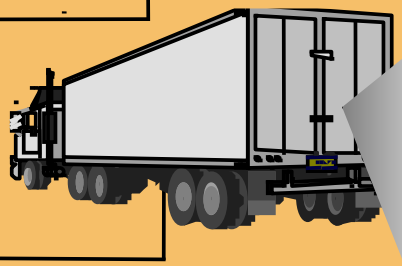






EMOTR

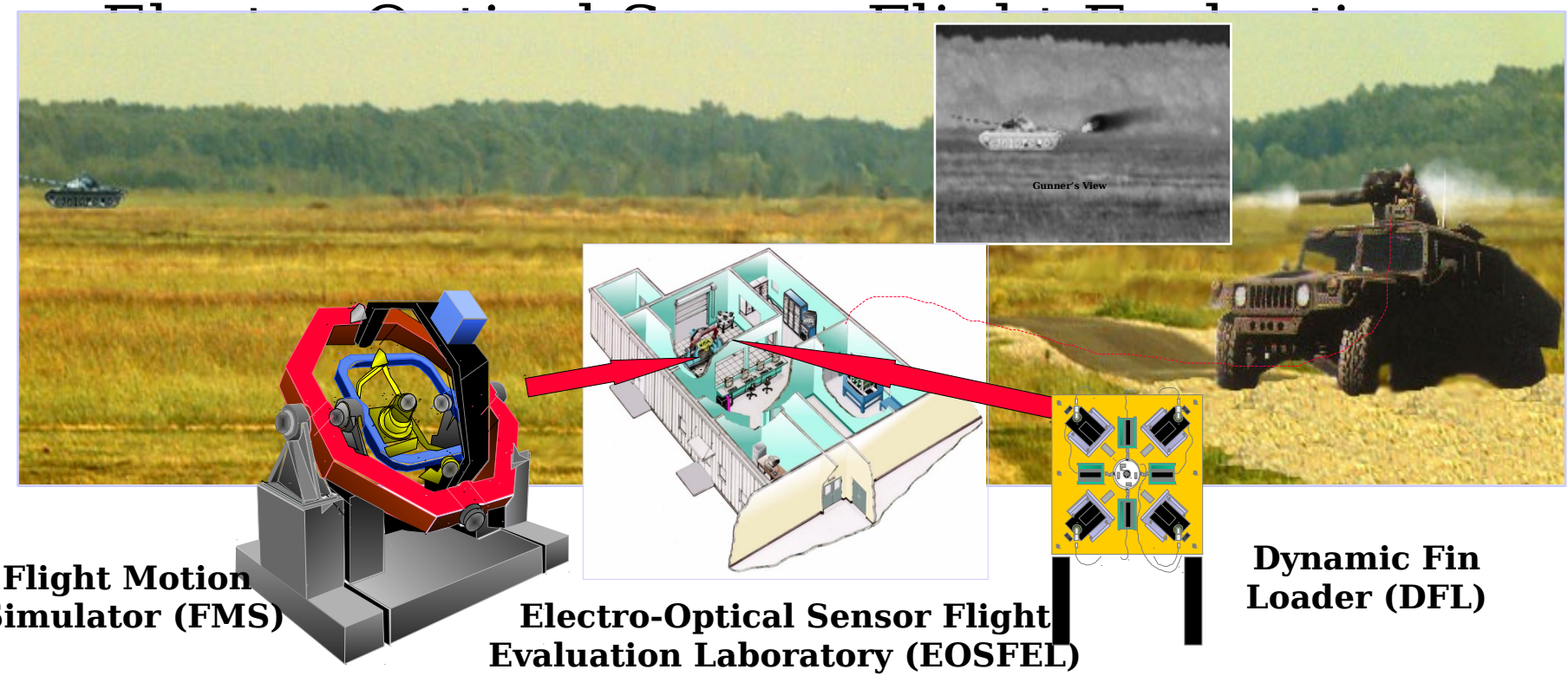
Distant Object Optics



Data Acquisition & Analysis & MC Vans

- MODELS (OF THE TRAJECTORY OF A PROJECTILE OR ROCKET, DEPLOYING MULTIPLE SUB-MUNITIONS) DRIVE TRACKING RADAR THAT CONTROLS THE VIDEO, FOCAL PLANE STARING ARRAYS, FILM CAMERAS, AND RANGING RADAR.
- INTEGRATED AND CONTROLLED BY HIGH-SPEED NETWORKS AND COMPUTERS.
- CAPTURES FLIGHT AND IMPACT DATA ON UP TO 40 SUB-MUNITIONS SIMULTANEOUSLY FROM CARRIER VEHICLE DISBURSEMENT TO IMPACT.

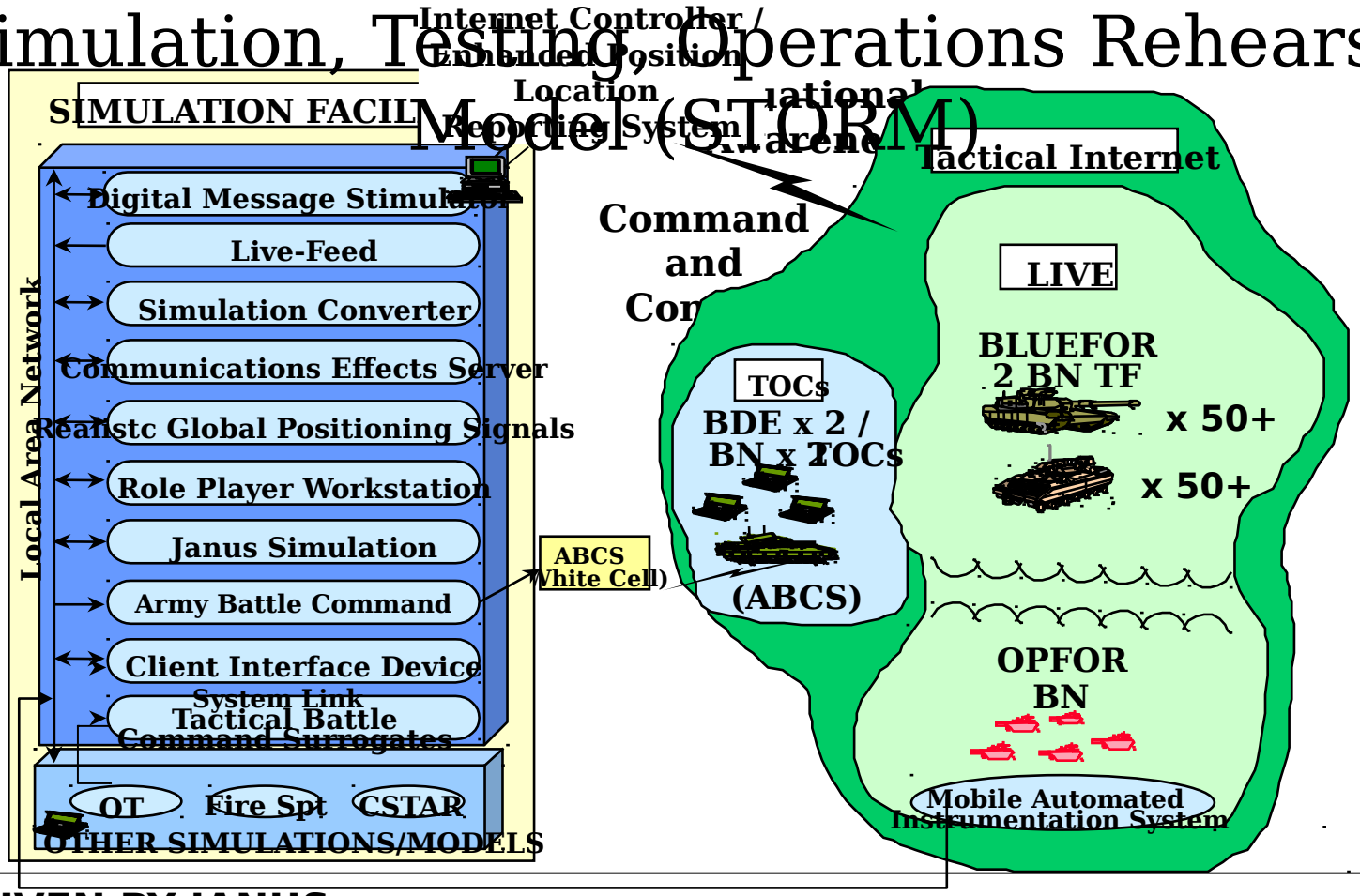
M&S Integration with Testing (Create System Loading)


Gunner's View
Flight Motion Simulator (FMS)
Electro-Optical Sensor Flight Evaluation Laboratory (EOSFEL)
Dynamic Fin Loader (DFL)

INFRARED-SEEKING TACTICAL MISSILES ARE IMMERSED IN SYNTHETIC FLIGHT ENVIRONMENTS TO EXERCISE THE ENTIRE MISSILE SEEKER/GUIDANCE AND CONTROL SYSTEM AND SUB-SYSTEMS. THE HARDWARE-IN-THE-LOOP FACILITY PRESENTS DYNAMIC IR SCENES THAT INCLUDE TARGET SIGNATURE AND MOTION, TERRAIN FEATURES, NATURAL AND MAN-MADE OBSCURATION, AND FOLIAGE, TO THE SEEKER. THE MISSILE AIRFRAME "FLIES" IN A 6 DEGREE-OF-FREEDOM FIXTURE THAT PROVIDES CLIMATIC CONDITIONING, DYNAMICALLY LOADS ITS CONTROL

M&S Integration with Testing (Test Scenario Driver)

Simulation, Testing, Operations Rehearsal Model (STORM)

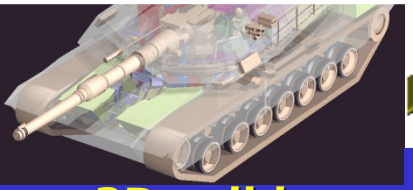


- DRIVEN BY JANUS
- CREATES A REALISTIC ENVIRONMENT FOR BRIGADE AND BELOW OPERATIONS,
- SIMULATES PHENOMENA, AND DISTRIBUTES INPUT MESSAGES TO LIVE PLAYERS FOR SCENARIO GENERATION, TEST REHEARSAL, SIMULATION, STIMULATION, DATA COLLECTION, REDUCTION, VISUALIZATION AND ANALYSIS OF C3I SYSTEMS

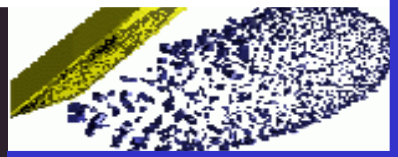
M&S Integration with Testing (Post-test Analysis/Evaluation /Assess Vulnerability and Lethality)

Vehicle Ballist ty Testing

MODEL



3D solid geometric model of system



Characterize target/threat interaction

Characterize component failure on subsystem capability (Fault trees)

Characterize system functionality (Mobility, Firepower,…)

ID Data Voids

Select Components

Design Component Tests

Calibrate Model

Model Damage

Model Effect of Damage on Components

Expand Model

TEST

- Penetration
- Spall
- Shock/pressure

- Component damage

- Controlled damage
- Subsystem

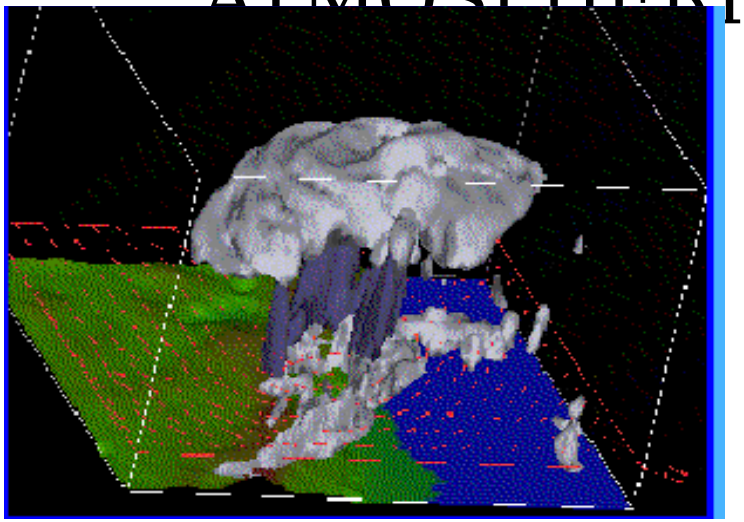
Design LF Test

System-level (LFT&E)

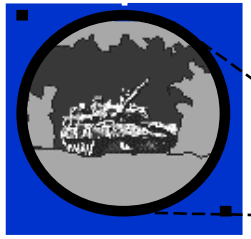
Development

M&S Integration with Testing (Examine Alternative Environments)

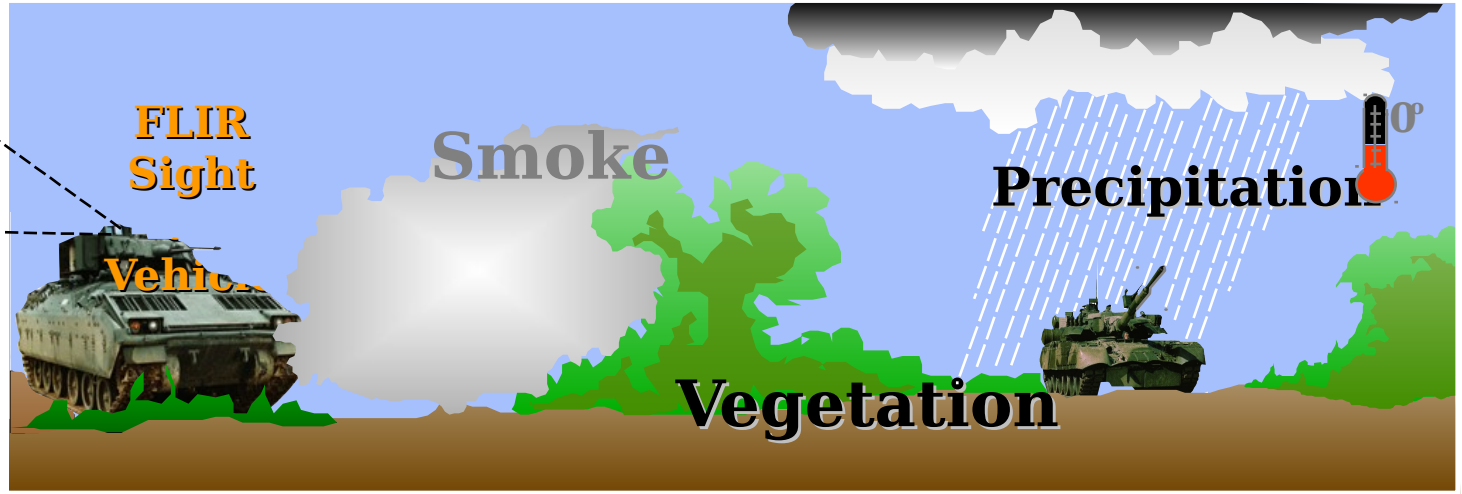
ATMOSPHERIC EFFECTS MODELING



Atmospheric Effects Modeling provides the tools to synthesize atmospheric effects that can be used to predict the movement of missiles, chemical/biological threats, and obscurant clouds. Synthetic atmospheric effects can be superimposed on electro-optical scenes for hardware-in-the-loop stimulation and human-in-the-loop simulation, or to influence the signal transmission/receiving performance in computer-based simulations of communication networks.

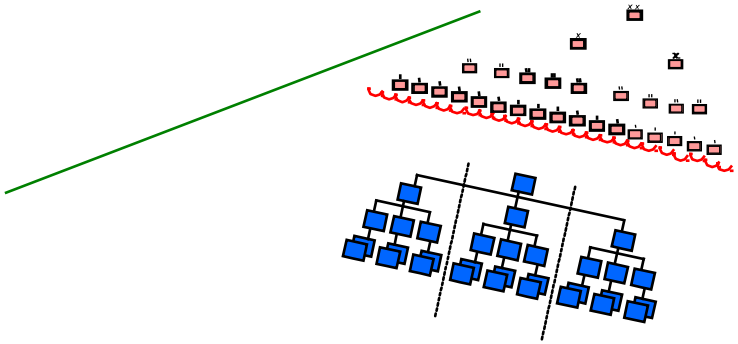


FLIR View



M&S Integration with Testing (Extend Test Results to Battlefield Effectiveness)

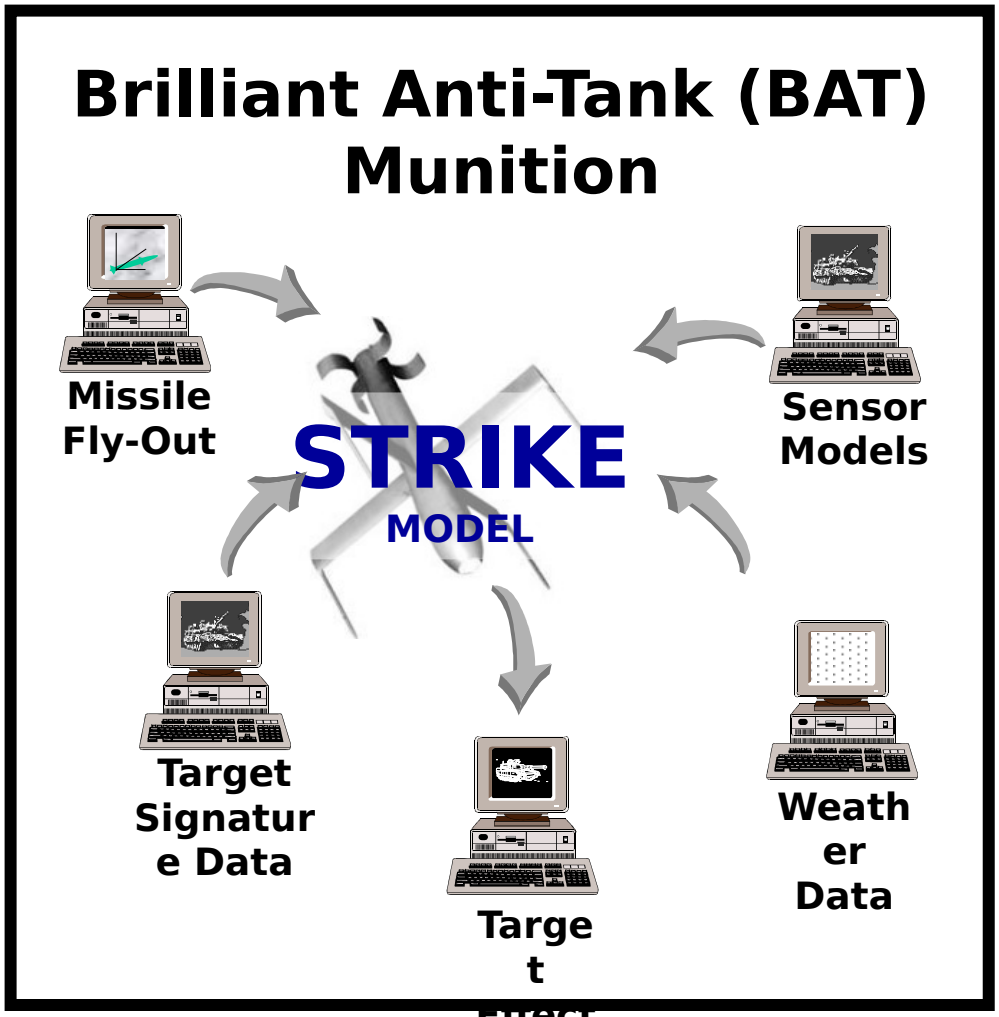
Operational Test – Tactical Engagement System (OT-TES) Janus, CASTFOREM



ACCURACY AND DISPERSION TEST DATA AND MUNITIONS EFFECTIVENESS MODELS ARE USED TO PREDICT PROBABILITY OF HIT AND PROBABILITY OF KILL FOR A WEAPON SYSTEM UNDER SPECIFIC CONDITIONS. OUTPUTS ARE USED AS INPUT TO REAL TIME CASUALTY ASSESSMENT SYSTEMS, SUCH AS MAIS, FOR SCORING OPERATIONAL TESTING, AND TO COMBAT MODELS SUCH AS JANUS OR MODULAR SEMI-AUTOMATED FORCES (MODSAF) FOR ASSESSING BATTLEFIELD CONTRIBUTION TO FORCE EFFECTIVENESS. THOSE RESULTS MAY BE PROJECTED TO HIGHER ECHELONS (BRIGADE AND ABOVE) USING THE COMBINED ARMS AND SUPPORT TASK FORCE EVALUATION MODEL (CASTFOREM) AND THE EMERGING JOINT CONFLICT AND TACTICAL SIMULATION (JCATS) WARGAME MODELS.

M&S Integration with Testing (Extend Test Results to Battlefield Effectiveness)

STRIKE Model



Input:

- Missile Data
- Meteorological Data
- Target Signature
- Target Geometry

Output:

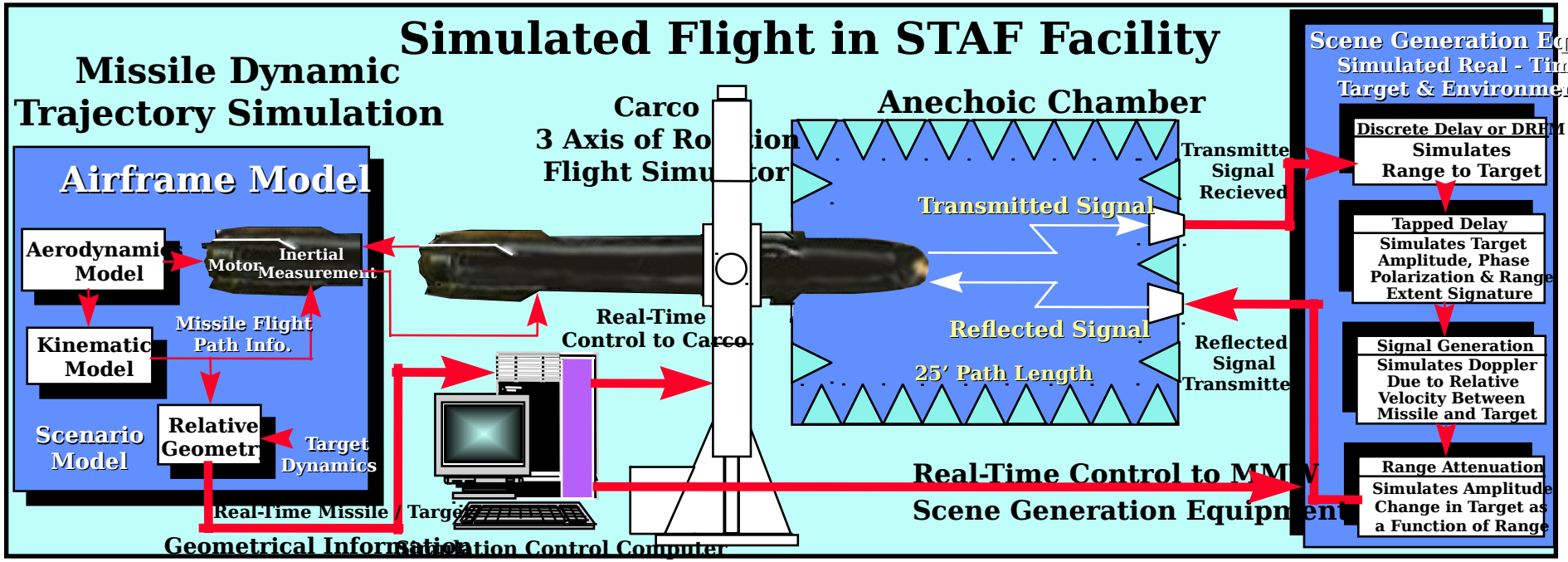
- Fly-Out
- Sensor Performance
- Target Effects

Uses:

- Test Planning
- Firing Solutions
- Analysis of Untested Conditions

M&S Has Improved Efficiency/Reduced Cost

Simulation / Test Acceptance Facility



Non-Destructive Stockpile Testing

- **PROVIDES HARDWARE-IN-THE-LOOP TESTING OF A FULLY ASSEMBLED "LIVE" MILLIMETER WAVE RADAR-GUIDED MISSILES WITH MULTIPLE COMPUTER-BASED TEST SCENARIOS.**

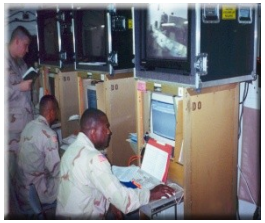
- **THE STAF ALLOWS 100% TESTING OF PRODUCTION MUNITIONS ROUNDS IN A REAL-TIME NON-DESTRUCTIVE SIMULATION.**

M&S Has Improved Efficiency/Reduced Cost

Firing Impulse Simulator (FIS)

- **SAVED ABOUT $2,000 PER ROUND**
- **DELIVERS APPROXIMATELY 3 MILLION POUNDS OF FORCE**
- **TEST CREW REDUCED FROM 13 TO 4**
- **TIME SAVINGS AND ENVIRONMENTAL BENEFITS SUCH AS NOISE, TOXIC FUMES, BLAST OVERPRESSURES HAZARD, AND RANGE CLEAN-UP**
- **REPLICATES ACTUAL FIRING WITHOUT AMMUNITION, NOISE, TOXIC FUMES, BLAST OVERPRESSURES, AND RANGE CLEAN-UP**

U.S. Army Space & Missile Defense Command
Modeling & Simulations Computational Facilities



Advanced Research Center (ARC)
State of the Art Computer Facility that supports numerous DoD Missile Defense
an

SMDC Simulation Center (SC)
Provides scientific and engineering Supercomputer support for the SMDC mission of research and development of futu Space and strategic defense applications an related technologies.

The ARC and SC jointly operate as a High Performance Computing Modernization Program Office Distributed Center.

Joint Experimentation M&S Future Challenges

- ☑ Joint model interoperability
- ☑ Multi- level fidelity
- ☑ Multi- level security
- ☑ Increased permanent network infrastructure
- ☑ Rapid database building
- ☑ Integrated w/ current & future C4I systems
- ☑ Improved modeling of individual and group behavior
- ☑ Balanced Warfare Representation and associated VV&A cost
- ☑ Course of action analysis & mission rehearsal

Identification of M&S Needs

- **ICD/ CDD/ CPD /TEMP / SEP**
- **Simulation Support Plan (SSP)**
- **Implementing M&S**
  - **Live vs. Simulation Considerations**
  - **Verification, Validation, Accreditation**

Identification of M&S Needs

The Evaluation Planning Process

- **M&S & tests are mutually supportive vice competing, isolated, or duplicative.**
- **ATEC System Team (AST), in collaboration with the T&E Working-level Integrated Process Team (T&E WIPT), is the forum for developing the system-level T&E strategy. Based on requirements identified in:**
  - Initial Capabilities Document (ICD)
  - Critical Operational Issues and Criteria (COIC)
  - Supporting documents such as:
    - **Test and Evaluation Master Plan (TEMP)**
    - **Analysis of Alternatives (AoA)**
    - **Simulation Support Plan (SSP)**
    - **Threat assessments**
    - **Mission area strategies**
- **The SSP and the M&S section of the TEMP must reflect the results of M&S planning for T&E**

Identification of M&S Needs

Drafting the System Evaluation Plan (SEP)

- **Examine requirements documents to identify aspects of system capabilities essential for mission accomplishment.**
- **Establish measures of effectiveness (MOE) and measures of performance (MOP) to quantify the needed capabilities.**
- **Identify existing sources and planned activities, within the PM's acquisition strategy, that can provide data for the measures.**
- **Propose dedicated events to generate required data to fill information voids.**
- **Sequence and optimize those events to focus on the specific, relevant unknowns.**
- **Develop the data source matrix (DSM).**
- **Coordinate the draft SEP with the T&E WIPT to ensure that all credible,**

Selection of M&S Tools

1 of 3

- Coupled with selection of live test events.
- Ensure approach to execute evaluation strategy is most cost-effective.
- Need to validate data sources.
- Live tests
  - ✓ Verified for efficient and effective design
  - ✓ Validated to ensure that environmental conditions are appropriate and sufficient, and that specific issues (information voids) are adequately addressed.
- M&S
  - ✓ Verified for logical stepwise process and use of sound software engineering techniques;
  - ✓ Validated for output, relative to input, that is comparable to real world observations; and officially accepted (accredited) as a source of credible data for a specific application.

Selection of M&S Tools

- **Uses of M&S in T&E**
  - ✓ **Pure simulation (computer testing a model of a system),**
  - ✓ **Man-in-the-loop simulation, live (hardware) testing supported by simulation,**
  - ✓ **Simulation supported by live test data.**

- **Questions to consider:**

1. What M&S are available to provide insight into how the new system might affect the mission?
- **Models that reflect system performance characteristics**
- **Models of threat systems**
- **Combat models that are sensitive to modeled system performance characteristics**
- **Synthetic stimuli and environments that influence modeled system performance characteristics.**

2. What evaluation questions need to be answered?

3. What M&S, including threat M&S, can be used to extend the analysis of available data, or of data from planned live tests?

Selection of M&S Tools

- **Questions to Consider (continued):**

4. What are the limitations of the live test events we must perform, that may be overcome through the use of M&S?

5. What well-understood aspects of the system's performance might be modeled, to focus testing on unknown aspects?

6. What are the verification and validation (V&V) requirements for the available and proposed M&S tools?

7. What tests or other sources will be required to validate models?

8. What M&S can be used to plan or rehearse live test events?

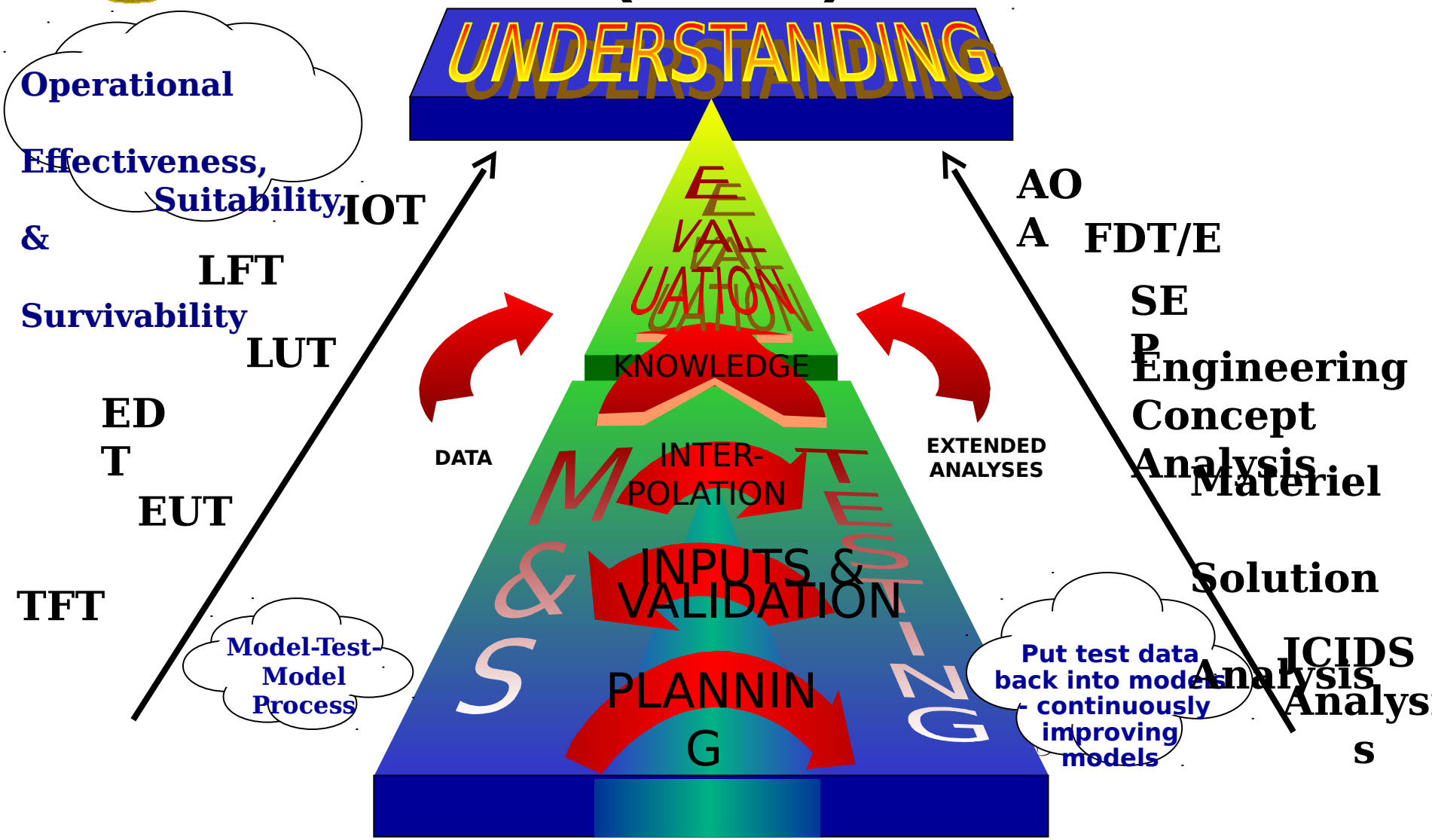
Selection Considerations

- **M&S selection will include consideration of the following:**
  - **Output relates directly to required MOE and MOP.**
  - **Inputs are known, or readily available from testing or other sources.**
  - **Required assumptions are known, valid, credible, and defensible.**
  - **M&S are compatible with available computer platforms, system stimulators, hardware/human-in-the-loop simulators, and other models with which it will interact.**
  - **M&S can be modified at a cost, if necessary, to meet acceptability criteria.**
  - **M&S selected is consistent with those used, or is acceptable for reuse, elsewhere in acquisition process (concept exploration, design, manufacture, training, and maintenance).**

Selection Considerations

- **M&S selection will include consideration of the following (continued):**
  - **M&S present output data in a way that facilitates the evaluation process.**
  - **M&S provide relevant, realistic, controllable, repeatable, affordable synthetic environment or stimulus.**
  - **Use of the M&S reduces the time or cost of a live test event.**
  - **Government has data rights to model.**
  - **Degree to which the M&S have undergone V&V, or are sufficiently documented to allow affordable V&V and accreditation with minimal live testing.**

Simulation Test & Evaluation Process (STEP)



Using M&S Results in Evaluation

M&S Applications

M&S Type	Pre-test	Test	Post-Test
A	Estimate performance envelope. Plan & rehearse data acquisition.	Create loading with simulators and stimulators. Drive instrumentation.	Assess vulnerability Examine alternative environments.
B	Develop test scenarios and mission profiles.	Scenario driver for command, control, communications and intelligence.	Supplement test results. Examine effects of test limitations on evaluation.

Predict → **Observe** → **Apply**

Model → **Test** → **Model**

A - Engineering
B - Combat

TEMAC T&E Refresher Course

Test Results Use in M&S Validation

Test Applications

M&S Type	Pre-Test Model	Test	Post Test Model
A	Estimate weak M&S areas. Address M&S assumptions. Obtain missing M&S data.	Developmental Test conducted to fill M&S data voids.	Rerun M&S with actual test data to confirm validity of initial M&S results. Re-calibrate M&S with actual test data. Re-estimate M&S system performance.
B	Run M&S using estimated: - human performance - man-in-the-loop - doctrine - tactics, techniques, and procedures (TTPs)	Operational Test conducted to measure: - actual performance - combat doctrine - TTPs	Determine ROC to combat unit.

A - Engineering
B - Combat

TEMAC T&E Refresher Course

M&S and T&E Mutually Supportable

M&S Applications

M&S Type	Pre-test	Test	Post Test
A	Estimate performance envelope. Plan & rehearse data acquisition.	Create loading with simulators and stimulato Drive instrumentation.	Assess vulnerability Examine alternative environments.
B	Develop test scenarios and mission profiles.	Scenario driver for command, control, communications and intelligence.	Supplement test results. Examine effects of test limitations on evaluation.
	Predict → Model	Observe → Test	Apply → Model

M&S Types

A - Engineering

B - Combat

Test Applications

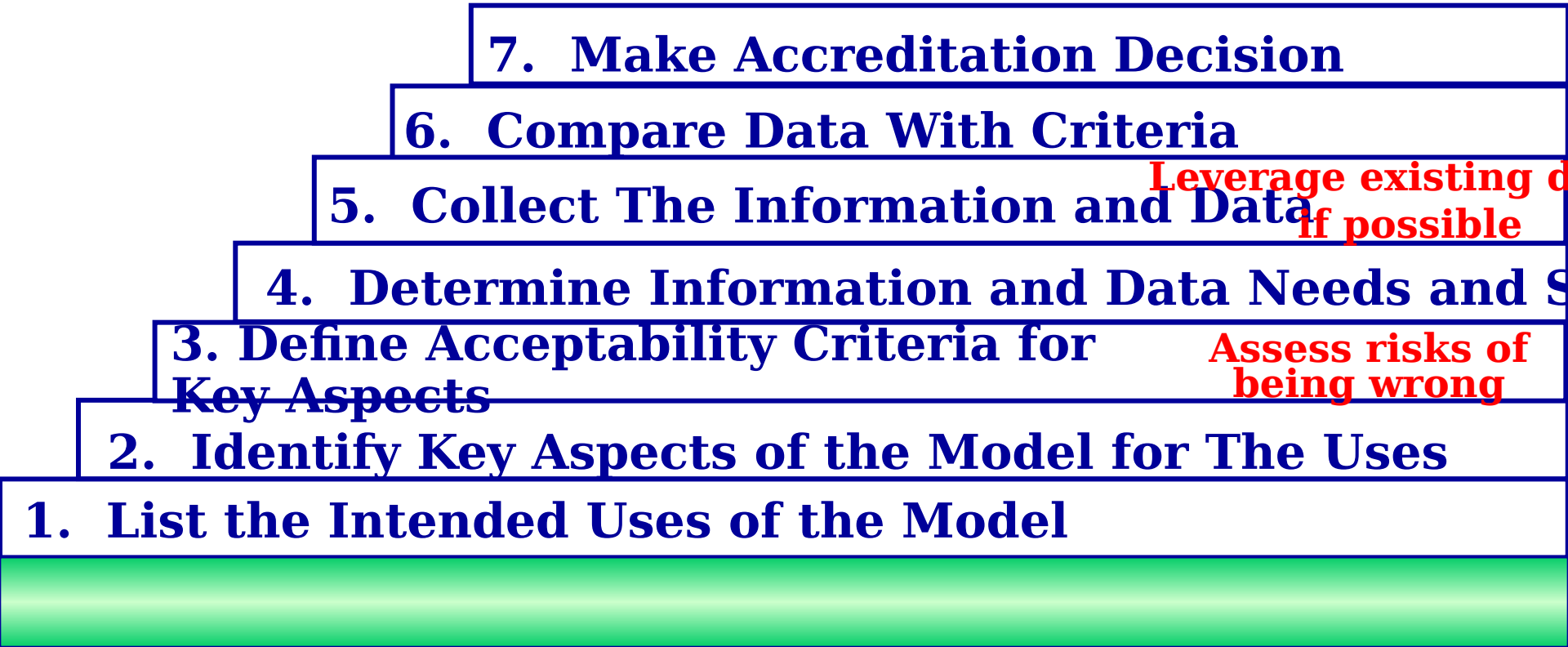
M&S Type	Pre-test	Test	Post Test
A	Estimate weak M&S areas. Address M&S assumptions. Obtain missing M&S data.	Developmental Test conducted to fill M&S data voids.	Rerun M&S with actual test data to confirm validity of initial M&S results.
B	Run M&S using estimated: - human performance - man-in-the-loop - doctrine - tactics, techniques, and procedures (TTPs)	Operational Test conducted to measure: - actual performance - combat doctrine - TTPs	Re-calibrate M&S with actual test data. Re-estimate M&S system performance. Determine ROI to combat unit.

T&E Accreditation

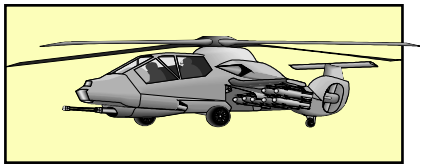
Any M&S Used to Support or Supplement T&E Must Be Accredited if the Results Influence the System Evaluation

The authority who approves the action based on the model or simulation, or approves the release of the document in which the model or simulation is directly or indirectly reflected, is the accreditation authority.

Accreditation Process Overview


7. Make Accreditation Decision
6. Compare Data With Criteria
5. Collect The Information and Data
Leverage existing d
if possible
4. Determine Information and Data Needs and S
3. Define Acceptability Criteria for Key Aspects
Assess risks of being wrong
2. Identify Key Aspects of the Model for The Uses
1. List the Intended Uses of the Model

Similar Processes



T&E

Evaluation Plan

Test Plan

Test

Test Report

Evaluation Report

Requirements

Know the Intended Uses

Identify Issues & Criteria

Determine Data Needs and Sources

Collect Data

Compare Data With Criteria

Decision

VV&A

Accreditation Plan

V&V Plan

Test

V&V Report

Accreditation Report

Acknowledgement & Feedback

This module is a part of the T&E Managers Committee (TEMAC) T&E Refresher Course.

Request your feedback. Please contact -

T&E Office
Deputy Under Secretary of the Army
102 Army Pentagon
Washington, D.C. 20310-0102
(703) 602-3508 / 2134 DSN: 332